Radiation Damage - Minimising the Dose and Maximising the Signal

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A summary of the present understanding of radiation damage in protein crystallography can be found in Garman and Nave 2009, in an issue which also includes other papers describing investigations of radiation damage. Ionising radiation can cause structural changes in soft materials due to a branching cascade of physical and chemical processes which take place on a variety of time and length scales. These processes will be briefly described.

One way of reducing the dose deposited in the crystal is by allowing the photo-electrons to escape and the effects of this have been simulated (Nave & Hill, 2005; Cowan and Nave, 2008; Stern et. al. 2009). There are some indications that this can work in practice (Moukhametzianov, et. al. (2008). By exploiting this effect, it should be possible to obtain data from smaller crystals and an estimate of the minimum size of crystal to obtain a processable image with a given unit cell and resolution will be given. This will be compared with the possibilities of looking at small crystals with a single pulse from free electron laser.

The resolution is normally determined by the region where the majority of diffraction spots are submerged in to the background. Diffraction spots from both room temperature and cryo-cooled crystal can have quite complex shapes on the micron scale (Stojanoff and Siddons, 1996; Nave, 1998; Kriminski et. al. 2002) with sharp features which should, if exploited, allow a better spot to background ratio to be obtained. This would require a combination of low emittance x-ray beams and detectors with high resolution. Ultimately use of a fully coherent x-ray beam should allow the domain structure of the crystal to be determined at sub micron resolution from the speckle effects around the more intense diffraction spots (e.g. Boutet and Robinson, 2008). Applying this knowledge to the weaker spots should allow improved intensity estimates to be obtained. It may even be possible to obtain estimates of the intensities of the two parts of a composite reflection from a perfectly merohedrally twinned crystal.

Low emittance x-ray beams can therefore be used to reduce radiation damage either by allowing photo-electron escape or by reducing the required exposure via optimising the recording of the diffraction data. Both of these possible approaches will be described.

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